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Peach bagging in the Southeastern U.S.

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Abstract

The control of pests and diseases is pivotal in producing high quality peaches in the humid climate of the Southeastern United States. Fruit bagging is proposed as a strategy to physically exclude pests, prevent disease development, and consequently help reduce the reliance on pesticides. Six peach trees from two cultivars (early and mid-season cultivars) were chosen from one organic farm and one conventional farm, and 150 fruit/tree were bagged with 75 being marked as control and left unbagged. In order to understand the effect of bagging on coloring, 50 bags were removed per tree 10 days before harvest. Fruit quality analysis (size, weight, SSC, acidity, color) and disease incidence were assessed at harvest and post-harvest. Bagging increased marketable yield at the organic farm but not at the conventional farm. Fruit quality (size, brix, acidity) of bagged peaches was similar when compared to non-bagged fruit. The intensity of the red blush of the peach was reduced for the bagged fruit compared to control fruit but peaches that were unbagged 10 days before harvest had blush comparable to the control. The effect of bags on postharvest disease incidence was not conclusive. Public surveys showed that potential consumers preferred bagged peaches and were willing to pay more for them when informed that the fruit had been less exposed to pesticides.

Conventional control practices for pests and diseases for peach production can reduce the sustainability and profitability of commercial orchards and can be challenging in regions with warm and humid climates such as the southeastern U.S. As a consequence, organic production of peaches under these climatic conditions is almost nonexistent because of high pest and disease pressure and the lack of OMRI-approved, efficacious chemicals (Ames, 2012). Nevertheless, peach had the highest demand among organic fruits in recent years; between 2008 and 2011 the value of the organic peach industry rose by 41%, and it expanded in both harvested acreage and harvested quantity, mostly in California, where dry summer conditions are ideal for growing fruit organically (Perez and Plattner, 2013). On the other hand, the frequent application of pesticides in conventionally-produced peaches in the southeastern U.S. is of environmental concern, may pose increased risks to workers and consumers, and promote pathogen resistance development. Thus, both organic and conventional orchards under these conditions could benefit from new techniques to help combat pests and diseases.

Fruit bagging is an extensively used practice in countries such as China and Japan (Sharma et al., 2014; Shen et al., 2014;) and on a smaller scale in other countries such as Spain (Faci et al., 2014). In the United States, fruit bagging has been used on a very small scale in commercial orchards on the West Coast to improve late-season red color development in 'Fuji' apples for export to Asian countries (Bessin and Hartman, 2003), and also for pollination of Calimyrna figs (Gerdts and Clark, 1979), but bagging has been considered impractical for most commercial growers. Fruit bags have been used for a wide variety of fruit crops including bananas, mangos, pears, apples, and grapes (Hofman et al., 1997; Fan and Mattheis, 1998; Amarante et al., 2002; Signes et al., 2007; Muchui et al., 2010). They are mostly used for pest and disease protection but also to manipulate aesthetic parts of the fruit such as color (Sharma et al., 2013) and produce unblem-

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ished fruits that meet consumer's high quality requirements. Depending on the purpose of the bag and fruit involved, single or double layer bags, yellow bags, and polyethylene plastic have been used (Kim et al., 2008; Xu et al., 2010; Muchui et al., 2010).

We hypothesized that fruit bags could be a valuable tool to reduce the incidence of pests and diseases, and increase marketable yields in organic orchards located in warm and humid climates such as the southeastern U.S. Fruit bags may also be used to produce high-quality peaches in conventional orchards for a premium market and reduce reliance on pesticides. The objectives of this project were to evaluate fruit bagging as a strategy to increase production of high-quality peaches in both organic and conventional farms, and to obtain consumer feedback on preferences and willingness to pay a premium for this product.

Materials and Methods

Orchard selection. This research was carried out in two commercial farms in South Carolina: one organic farm and one conventional farm. The organic farm was located in Monetta, SC. The conventional farm was located in Ridge Spring, SC. Two peach [*Prunus persica* (L.) Batsch] orchards were selected at each farm: one with an early-season cultivar and another one with a mid-season cultivar. The early-season cultivar was 'Crimson Lady' for both farms, and the mid-season cultivars were 'Scarletprince' and 'Julyprince' (for the conventional farm the original 'Scarletprince' block was removed after the first year and the second year we used a block of 'Julyprince' trees; for the organic farm, we used 'Julyprince' both years). All trees were mature trees, 7-10-year-old, grafted onto Guardian™ peach seedling rootstock, at a planting density of 346 trees per ha. The conventional orchards strictly followed a chemical spray program based on the current Southeastern peach, nectarine and plum management guidelines, including dormant sprays for scale and bacterial spot control, pre-bloom, bloom, and post-bloom for peach scab and blossom blight control, summer cover sprays for summer disease control, and preharvest sprays for brown rot control. One to three days before bagging, conventional trees were treated with captan and phosmet, while the organic orchards were treated with sulfur-based products, pyrethroids, and kaolin clay. All orchards were within 15 km from each other (Table 1) and the soil was well-drained sandy loam at both locations. Also, the environmental conditions were practically the same for all orchards. Precipitation from 1 March thru 30 May (bloom-harvest period for early-season cultivars) in 2015 and 2016 was 216 mm and 185 mm, respectively, with an average temperature of 17.4 ˚C for both years. Precipitation and average temperature between 1 March and 10 July (bloom-harvest period for mid-

Table 1: Location (latitude and longitude) and harvest date for each orchard and each year.

Orchard	Latitude / Longitude	Harvest date 2015	Harvest date 2016
Organic			
'Crimson Lady'	33° 50' 2.4" N / 81° 37' 21.7" W	May 26	June 3
'Julyprince'	33° 47' 39.8" N / 81° 35' 8.5" W	July 14	July 1
Conventional			
'Crimson Lady'	33° 49' 4.8" N / 81° 44' 7.1" W	May 26	June 3
'Scarletprince'	33° 49' 31.1" N / 81° 42' 7.9" W	July 6	-[z]
'Julyprince'	33° 49' 28.9" N / 81° 42' 31.3" W	-	July 1

[z] 'Scarletprince' trees at the conventional farm were pulled out after the first year of data and we used 'Julyprince' trees the second year.

season cultivars) was 473 mm and 19.5 ˚C in 2015, and 253 mm and 20.2 ˚C in 2016.

Experimental setup. The experiment was performed in a completely randomized design with six trees (reps) for each cultivar and orchard. In the third week of April 2015, when fruitlets were about 2.5 cm in diameter, right after thinning, seventy-five fruit per tree were tagged as control (non-bagged) fruit, and 150 fruit per tree were bagged. Ten days before harvest the bags of 50 bagged fruit were removed to evaluate the effect of sunlight on color (bagged-10d). Thus, three treatments were established: control, bagged, and bagged-10d fruit. At harvest, fruit were collected and separated by treatments: 75 control, 100 bagged, and 50 bagged-10d fruit per tree. The number of unblemished (marketable) and rotten/damaged fruit was recorded. Since there was no difference in color between the bagged-10d and control fruit for any of the locations and cultivars in 2015, the removal of bags ten days before harvest was not repeated in 2016. In 2016, fruit were tagged and bags were placed during the first week of May. The number of bagged fruit was reduced to 100 bags per tree with 75 tagged as control but everything else was the same as in 2015.

Fruit quality. Fruit was harvested when control fruit was at commercial ripening stage. Since the early-season cultivar ('Crimson Lady') was the same for both farms, fruit was harvested on the same date; for the mid-season cultivars, there was a difference of a few days between farms due to the slightly different ripening dates of 'Scarletprince' and 'Julyprince'. Size (diameter, mm) and weight (g) were measured using a Fruit Texture Analyzer (FTA; GÜSS, Strand, South Africa) from a subsample of five fruit (Frett et al., 2012) per treatment, per tree, per cultivar and location. Afterwards, fruit juice was squeezed from a composite sample comprised of two slices from each of the five fruit and subsequently used to measure soluble solids concentration (SSC), pH, and titratable acidity (TA). The SSC was measured with a temperature-compensated refractometer (model ATC-1, Atago Co., Tokyo, Japan), and data were given as °Brix. The pH and TA were determined by autotitration with 0.1 N NaOH to pH 8.2 (Titrosampler, Metrohm Riverview, FL, USA) and data were given as % malic acid per 100 g of fresh weight (FW). In addition, SSC/TA ratio was calculated.

Postharvest. At harvest, 30 fruit per tree, cultivar, and location were set aside for postharvest disease assessment. The fruit were stored in an air-conditioned room at 20°C and were evaluated three and seven days later to determine the incidence of brown rot.

Consumer surveys. Consumer surveys were conducted in two separate locations after fruit was harvested the first year. The first was at the local farmer's market in Clemson, SC where 57 participants agreed to be surveyed. The second location was on Clemson University's campus within walking distance of the downtown Clemson area where 29 participates agreed to be surveyed. A table was set up with two baskets of unlabeled peaches: control (never bagged) peaches, and bagged peaches. Participants were asked which batch of peaches they found more appealing. They were allowed to hold or smell the peaches but they did not taste them. The concept of bagging was then explained to the participant and then asked again which batch of peaches was more attractive. The final question was if the consumer would pay a premium for bagged peaches and, if so, how much that premium would be. Demographic data (sex, age and race) were recorded.

Data analyses. Data from each cultivar, commercial farm, and year were analyzed separately (i.e. each year, we compared bagged and non-bagged fruit from each cultivar separately, for both the organic and the commercial orchard). Data were subjected to analysis of variance (ANOVA) using JMP® 12.2.0 software (SAS Institute, Cary, NC). Percentage data was transformed using arcsine transformation and then subjected to ANOVA.

Table 2: Quality parameters for fruit at the organic farm including diameter (mm), mass (g), SSC (%) and TA (%). Data shown for "Crimson Lady' and 'Julyprince' for two years.

	2015				2016			
	Diam.	Mass	SSC	TA	Diam.	Mass	SSC	TA
'Crimson Lady'								
Control	61.3b[z]	113.5b	9.3	0.8a	61.8	127.6	9.3	0.6
Bagged	66.1a	139.0a	9.1	0.7b	61.2	125.7	8.6	0.6
'Julyprince'								
Control	69.2	183.9	10.7	0.9	59.8	111.3	11.1	0.8
Bagged	72.1	202.9	10.2	0.9	60.2	112.3	10.7	0.8

[z] Values within columns and season followed by different letters indicate significant differences at $P \leq 0.05$.

Results

Organic peaches. For 'Crimson Lady' in 2015, but not 2016, the bagged treatment had significantly higher values for size and mass, and lower TA than control (Table 2). 'Julyprince' showed no significant difference in fruit quality between treatments in both years. The color of the control and bagged-10d peach fruit was comparable; however, bagged peaches had less intense red blush (data not shown).

In 2015 for 'Crimson Lady', 69% of control fruit were marketable vs. 82% of bagged fruit. For 'Julyprince', 92% and 95% of the fruit were marketable for the control and bagged treatments, respectively, and the difference was not significant ($P \leq 0.05$; Fig. 1). For 'Crimson Lady' in 2016 there were 29% marketable fruit for the control treatment vs. 30% for the bagged treatment. For 'Julyprince', the control treatment had 88% marketable fruit and the bagged had 99% marketable fruit ($P \leq 0.05$; Fig. 1).

Regarding postharvest disease assessment, the control 'Crimson Lady' fruit in 2015 had 82% and 87% rotten fruit, and the bagged fruit showed 38% and 97% rotten fruit three and seven days after harvest, respectively (Fig. 2). Disease incidence of 'Julyprince' was lower in both experimental years likely due to the hotter and warmer summer months suppressing disease development. 'Julyprince' had 16% and 38% rotten fruit for the control treatment, and 7% and 28% for

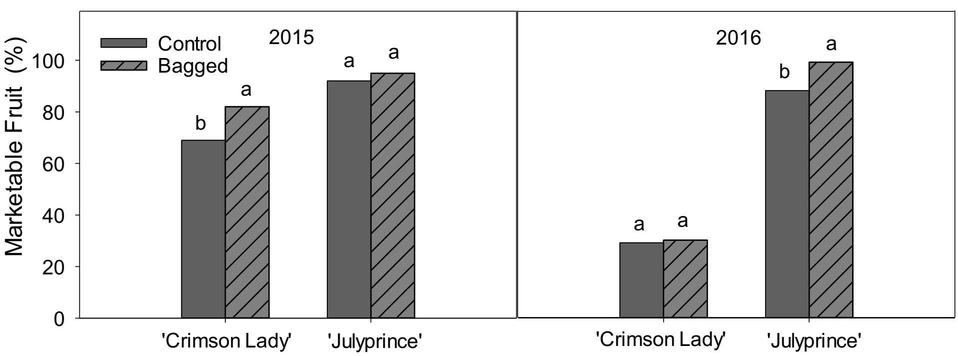

Figure 1. Percentage of marketable (unblemished) fruit at harvest for control (non-striped bar) and bagged (striped bar) treatments for 'Crimson Lady' and 'Julyprince' for two years. These data were collected at the organic farm. Values within year and season of maturity followed by common letters do not differ significantly at the 5% level.

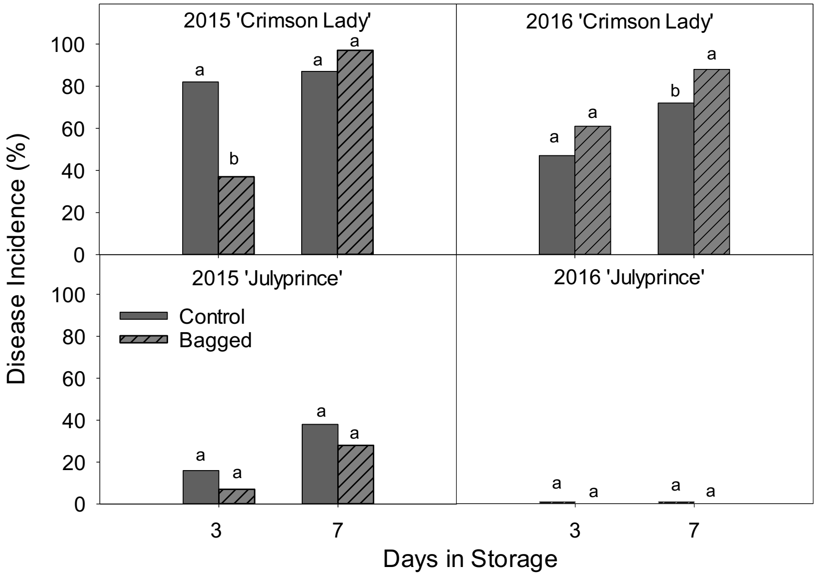

Figure 2. Incidence of brown rot after 3 and 7 days of storage at 20°C. Bagged and control treatments are shown for 'Crimson Lady' and 'Julyprince' for two years. These data were collected at the organic farm. Values within year and season of maturity followed by common letters do not differ significantly at the 5% level.

the bagged treatment, respectively. In 2016 'Crimson Lady' had 47% and 72% rotten fruit for the control treatment, and 61% and 88% rotten fruit for the bagged treatment, respectively. Virtually no storage rot was observed in any treatment for 'Julyprince'. None of the fruit showed symptoms of insect damage.

Conventional Peaches. 'Crimson Lady' in 2015 had significantly higher SSC for the control vs. the bagged fruit (Table 3). Bagging significantly increased fruit size and mass for 'Crimson Lady' and 'Julyprince' in 2016 (Table 3). All fruit was marketable at harvest for both years and both treatments (data not shown). Likewise, no post-harvest rot was observed, except for 'Crimson Lady' in 2016 when the fruit were improperly bagged after

Table 3: Quality parameters for fruit at the conventional farm including diameter (mm), mass (g), SSC (%) and TA (%). Data shown for 'Crimson Lady' and 'Scarletprince' (2015) and 'Julyprince' (2016) for two years.

	2015				2016			
	Diam.	Mass	SSC	TA	Diam.	Mass	SSC	TA
'Crimson Lady'								
Control	60.1	113.8	8.1a[z]	0.8	55.0b	93.9b	9.8	0.6
Bagged	59.3	108.6	7.5b	0.8	66.4a	161.6a	9.9	0.6
'Julyprince'								
Control	59.7	121.4	12.2	0.9	70.9b	183.6b	12.6	0.7
Bagged	61.8	135.7	12.3	0.9	74.5a	212.8a	12.5	0.8

[z] Values within columns and season followed by different letters indicate significant differences at $P \leq 0.05$.

a rain event (data not shown). Color development in conventional peaches was the same as described for organic peaches.

Consumer Surveys. Surveys at the farmers' market showed that when individuals were asked about their preference of the unmarked control and bagged peaches, 62% preferred the control fruit, 23% indicated no preference, and 15% preferred the bagged fruit, which had slightly less red color. When the concept of bagging was explained to the consumer and they were subsequently asked the same questions, 92% preferred the bagged fruit, 7% preferred the controls, and 1% had no preference. At the survey carried out near Clemson campus, 93% of participants initially preferred the control peaches, but most changed their minds and 86% then preferred bagged fruit. The average increase in price individuals at the farmers market were willing to pay was $0.38 extra per pound for bagged fruit, with 35% people answering $0.50 or more (85% of these were women) whereas at the Campus survey the average premium was $0.25 extra per pound.

Discussion

Bagging did not significantly affect fruit size, mass, SSC, and TA consistently between years or location. Bagged fruit for 'Crimson Lady' at the organic farm in 2015 and both 'Crimson Lady' and 'Julyprince' from the conventional farm in 2016 had a larger mass and size than non-bagged fruit. Since commercial peach fruit sizing is categorical (based on diameter) these differences did not change the fruit size category and would have no impact on price for the grower. Fruits respond differently to bagging in term of size and mass, for instance some fruits such as date palms, mangos, longan, and carambola had increased size when bagged (Harshash and Al-Obeed, 2010; Watanawan et al., 2007; Xu et al., 2008; Yang et al., 2009), but other fruits such as loquat and some 'Conference' pears had reduced size (Hudina and Stampar, 2012; Xu et al., 2010). On the other hand, bagged 'Crimson Lady' fruit tended to have lower SSC and TA than control fruit but differences were not significant for all years and locations.

For the conventional farm the only difference in fruit quality occurred in 2015 for 'Crimson Lady' for SSC and for size and mass in 2016. For peach there have been some instances where the fruit SSC was lower for bagged fruit vs. control fruit (Li et al., 2001) but our experiments did not show that trend. Lower SSC was reported for other bagged fruits such as pear, apple, mandarin, and plum (Chen et al., 2012; Hiratsuka et al., 2012; Lin et al., 2008; Murray et al., 2005). Treatments did not affect marketable yield in the conventionally grown fruit because fruit from both treatments did not rot preharvest or postharvest likely due to successful IPM implementation at this farm.

Color development of fruit while bagged depends on factors such as time of bagging, type of bag used, and timing of bag removal. Bagged peaches in this study did show a difference in red color intensity but not as drastic as reported in other fruits. For instance, apples had drastic color reduction, especially red-finish apples, if the bag was kept on the fruit until harvest. If the bag was removed three to four days before harvest, the exposure to UV light gave the fruit a deeper red color than before (Bai et al., 2016; Fan and Mattheis, 1998; Shen et al., 2014). For this reason, double layer bags can be used to help improve color. The first layer is opaque and has 0% transmittance of light but can be removed before harvest to allow light to the fruit. The second bag still gives the fruit the same protection while allowing light transmittance. This practice cannot be done in the United States due to high cost of labor of partial and eventually complete unbagging the fruit (Huang et al., 2009; Xu et al., 2010).

Regarding postharvest quality, the bags helped reduce the amount of postharvest brown rot for three days at the organic farm in 2015 but results were not consistent for both years. Numerous factors influence postharvest brown rot infections such as amount of rain prior to or at harvest (which was the main cause of yield reduction for 'Crimson Lady' in 2016), number and type of fungicide sprays prior to harvest, amount of inoculum present, and postharvest treatments. The data for the conventional farm are not shown because there was no postharvest rot in any treatment even after 7 days of incubation.

Marketable yield (i.e. amount of harvested fruit without blemishes caused by pests or diseases) of bagged fruit was higher than that of control fruit in the organic setting. The overall decrease in yield observed for 'Crimson Lady' in 2016 was a consequence of bagging the fruit immediately after a rainfall. The rain probably washed off the previous application of OMRI-approved fungicide spray and fruit were bagged while still wet. We did not see symptoms of insect damage, and fruit rot diseases were the main factor that caused reduction in marketable yield. Also, bagging did not affect harvest time (data not shown). Wang et al. (2010) reported that peaches of the cultivar 'Wanmi' had a harvest date around one month ahead of schedule when bags were used but we did not observe any change in ripening between bagged and non-bagged fruit.

Bagging is an agricultural practice that can be costly but can also produce some cost savings. The decision to use bags to help exclude pests and diseases is based on factors such as packout yield, organic certification, scale of farm, labor availability, increase in profitability, and costs. The addition to adding fruit bags to the farm's IPM program could be costly due to increased labor and material cost, but could also reduce the amount and frequency of sprays of expensive pesticides needed throughout the season and boost prices. However, the trees would still have to be protected throughout the season from damaging insects such as scale or damaging pathogens such as *Pseudomonas* sp., *Botryosphaeria* spp., *Phomopsis* sp., and *Leucostoma* sp. Those pathogens may be controlled, however, with cheaper products and in greater application intervals.

To understand the consumer's view on this new agriculture practice, surveys were conducted. When asked, surveyed individuals initially tended to prefer the deep red color of the control peaches but after the concept of bagging was explained, color was no longer the decisive factor. The overwhelming consensus was that fruit exposed to less pesticides were preferred. Consumers indicated willingness to pay a 0.38 cents per pound average premium for bagged peaches over the current price. These data indicate growers could benefit of marketing strategies directed to niche markets. If the labor force was available, the increase in price could help offset the cost of bags and extra labor involved. For instance, if a farmer harvests 113 kg of fruit per tree and sells them at a price increase of \$0.84/kg, the potential profit per tree would be \$80. On the other hand, based on our field trials, it takes about one hour for a worker to bag an entire mature tree. At the current price of \$12.00 per hour for labor, and bags themselves running about \$3.00 for one mature tree (400 fruit), the farm has the potential to profit for up to \$65.00 per tree from bagging, depending on marketing strategies and number of intermediaries. This amount can also increase if the farm's packout increased by using the bags. Positive results were reported for bagged lychee fruit in Hawaii; when lychee fruit was bagged there was an increase in marketable yield from 57% to 84% and had a potential to earn \$173 per tree if the fruits were bagged (Kawabata and Nakamoto, 2013).

On the other hand, conventional farms have already low losses due to pests and diseases because of strict spray schedules and use of efficacious chemicals. Thus, the addition of bags is not expected to increase marketable yield for these farms. Nevertheless, they may find opportunities when marketing these fruit as prime fruit, for instance, "grown-in-bag" peaches. The idea of fruit bagging appeals to consumers since peaches are known as one of the most highly sprayed fruit on the market; thus, bagged peaches could be sold at a premium at some niche markets.

One of the downsides to using bags is the loss of crop if they are not utilized correctly. The bags need to be placed on the fruit when they are dry and shortly after they were sprayed. If there is any moisture left on the fruit and tree from dew or a storm event the day before and the fruit has not been sanitized, a small amount of disease inoculum can cause rot and other detrimental problems for the fruit. Training workers to properly secure bags onto branches is also important for the success of the bags. If tied properly the bags are able to withstand high winds and heavy thunderstorms.

Overall adding fruit bags to the IPM regiment is a double-edged sword but may be beneficial for some farms. The bags do not affect fruit quality other than slightly reducing red color, but could help improve yield for the farm if utilized properly. The integration of bags could also help reduce the amount of pesticides needed, which in turn may reduce costs. The "grown-in-bag" fruits are viewed positively by consumers and could potentially be sold at a higher price to help offset the price of the bags.

Acknowledgments

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Correction:

On the web page (https://www.pubhort.org/aps/72/72.htm#2018_7_3) for volume 72(3), for the article by Mehmet Sutyemez, Akide Özcan, and Ş. Burak Bükücü "Walnut Cultivars Through Cross-Breeding: 'Dirilis' and '15 temmuz'", the last author's name was misspelled as Özkan and should be Özcan.